

**NOAA Coral Reef Conservation Program  
Land-Based Sources of Pollution Working Group**

**Threat Based Priority Strategic Goals and Objectives**

It is now well accepted that many major coral reef ecosystem stressors originate from land-based sources, most notably, toxicants, sediments, and nutrients. Within the U.S. and its jurisdictions, there are numerous locations where coral reef ecosystems are highly impacted by watershed alteration, run-off, and coastal development (Bellwood *et al.*, 2004; Pandolfi *et al.*, 2003; Richmond *et al.*, 2007). The importance of identifying the extent of and reducing these effects has now become crucial, as land-based pollution and coastal development put 22% and 30%, respectively, of coral reefs on Earth at risk (Bryant *et al.*, 1998). The April 2004 Report of the U.S. Commission on Ocean Policy highlighted the need for “an ecosystem and watershed-based management” approach to ocean pollution, and identified both “the astounding decline of coral reef ecosystems” and “an urgent need to address the identified, major factors causing coral declines” (Commission on Ocean Policy, 2004).

The suite of problems facing coral reef ecosystems from land-based sources of pollution is broad and includes sediment, nutrients, and other pollutants from a variety of land-based activities that are transported in surface waters, runoff, groundwater seepage, and atmospheric deposition into coastal waters. There is compelling evidence that the sources have increased globally as a result of human-induced changes to watersheds (Wilkinson, 2008). On the U.S. islands in the Pacific and Caribbean, significant changes in the drainage basins due to agriculture, deforestation, feral grazing, fires, road building and other construction, and urbanization have in turn altered the character and volume of land-based pollution released to adjacent coral reef ecosystems (ISRS, 2004). Many of these issues are further exacerbated due to specific characteristics exhibited in tropical island areas, all of which create unique management challenges when addressing land-based sources of pollution issues. A few examples include: high levels of rainfall; extreme weather events (hurricanes/typhoons); highly erodible soils; limestone hydrologic features, (Pacific atolls); and in some “high” islands, (American Samoa, Hawaii), steep slopes abutting the coastal zone.

Sedimentation, including higher levels of suspended sediment in overlying waters, is commonly acknowledged to be one of the primary causes of coral reef ecosystem degradation (e.g., Rogers, 1990; Field *et al.*, 2008). The combination of suspended, re-suspended, and deposited sediment act to limit coral growth, feeding patterns, photosynthesis, recruitment, and survivorship, as shown by numerous studies in a variety of settings (Fabricius, 2005). Other impacts of sediment include directly smothering and abrading coral. Although some corals can flourish in turbid water, such reefs are typically less diverse and are more restricted in depth ranges than those in clear water (Fabricius, 2005). To underscore this point, the U.S. Commission on Ocean Policy reported that “pollution and run-off from coastal areas also deprive reefs of life-sustaining light and

oxygen” and many Local Action Strategy (LAS) groups of the U.S. Coral Reef Task Force have identified land-based pollution to reefs as a major area of concern.

In addition to sediment, land-based sources of pollution to coral reef ecosystems include pesticides, petroleum hydrocarbons, pharmaceuticals, heavy metals, pathogens, and excess nutrients. These pollutants can cause or exacerbate the deleterious effects of watershed transport of pollutant constituents onto coral reefs (Richmond, 1993). Excess nutrients, including dissolved nitrogen and phosphorus from sewage, wastewater, and fertilizers, promote the growth of algae that compete with juvenile and adult corals for space on benthic reef surfaces and can affect success of coral settlement (Sammarco, 1996) and in extreme cases can result in eutrophication of reef waters. In addition, land-based inputs may both directly contribute land-derived pathogens and/or exacerbate the effect of *in situ* pathogens on coral reef ecosystems.

Finally, the local impacts of land-based sources of pollution work in synergy with global and regional threats such as climate change, land use practices, and freshwater inputs, magnifying the effect of both types of stressors. In particular, the potential for increased frequency and intensity of storm events associated with climate change could exacerbate run-off of sediment and other pollutants (UNFCC, 2002).

The three primary Goals of the CRCP’s plan to address land-based sources of pollution include:

- Reduce pollutant loading from watersheds to priority coral reef ecosystems;
- Promote in-water management activities to restore priority coral reef ecosystems that have been adversely impacted by accumulated sediments, nutrients, and algae; and
- Build and sustain management capacity at the local level through local, state, regional, and Federal coordination of financial, institutional, and human resources to reduce and prevent the impacts of land-based sources of pollution on coral reef ecosystems.

Partnership with other entities that have jurisdiction over or have a particular expertise related to land-based sources of pollution is essential to most effectively address this threat. The NOAA CRCP is committed to work in strong partnership to strategically build on and enhance on-going activities and to identify new opportunities to make demonstrable progress in decreasing the sources of and impacts from land-based sources of pollution on coral reef ecosystems. What follows are the guiding Goals and Objectives to establish this new strategic direction.

### **GOAL 1: Reduce pollutant loading from watersheds to priority coral reef ecosystems.**

Recognizing the profound link between watershed land use activities and the quality of the nearshore marine ecosystems, reducing or eliminating pollutant loads to coral reef ecosystems from land-based sources is paramount. Because sediment deposition and

algal cover often degrade coral reefs, reducing sediment and nutrient loading from urban/agricultural runoff and wastewater discharges should be a primary focus of watershed management activities. Debris, pathogens, and toxicants, including petroleum hydrocarbons, pesticides, heavy metals, and pharmaceuticals derived from the land are also pollutants of concern.

The health of many U.S. coral reef ecosystems ultimately depends on effective management of land-based activities in adjacent coastal and upland regions. Watershed assessment, planning, and restoration efforts to address land-based sources of pollutants should be conducted locally from ridge to reef, preferably in watersheds draining to high quality and/or restorable coral reef ecosystems. Comprehensive watershed management includes the application of land use planning; land conservation; vegetated buffer protection; environmentally sensitive development techniques; storm-water management (construction and post-construction); wastewater and drinking water management; and stewardship activities. To effectively address the impacts of land-based sources of pollution on coral reef ecosystems, it is essential that as watershed management plans are developed, updated, and implemented specific coral reef ecosystem protection measures are incorporated. Implementing best management practices and regulatory controls on the landscape is critical to reducing pollutant loads and improving coral reef ecosystem health.

An important component of watershed management, and hence, our efforts to protect coral reef ecosystems from land-based sources of pollution, is the conservation of the habitats that serve to limit rates of erosion and quantities of transported sediment and other pollutants to adjacent coral reef ecosystems. To support and enhance this buffering capability, preserving the natural state of forests, stream valleys, riparian zones, deltas, wetlands, and mangroves is a key to maintaining hydrologic functions including stream flow and ground water recharge. It is therefore essential to maintain or restore coastal and upland ecosystems as a first line of defense to limiting land-based pollution inputs and impacts to near-shore and coral reef ecosystems.

Supporting our watershed restoration and protection efforts with strategic research, implementing research applications that have direct management implications, and conducting the necessary performance monitoring are critical components to improving effectiveness in reducing pollutant loads, measuring progress, and incorporating adaptive management regimes.

The objectives outlined in this Goal are founded on identifying and working in select coral reef ecosystems that exhibit the greatest potential for recovery upon implementing conservation and management strategies. Identification of these coral reef ecosystems will take into account watershed activities, pollutant loads, the potential for reducing pollutant loads and land-based sources of pollution, and the vulnerability of the receiving marine ecosystem. Efforts will then focus on working in partnership to implement watershed management plan activities, which include the potential need to conserve and/or restore coastal and upland habitats; conducting strategic and applied research, and monitoring for adaptive management. Managers, communities, and decision-makers

need to support a broader and more comprehensive approach to watershed management that includes consideration of coral reef ecosystems. Successful implementation of this Goal is inextricably linked with the activities outlined in Goal 3.

**Objective 1.1:** Identify and prioritize those coral reef ecosystems and associated watersheds, within each jurisdiction, that will benefit the most from implementing management conservation strategies to reduce land-based sources of pollution.

*Potential activities include:*

- *Compile existing lists, reports, etc. that have identified priority coral reef areas and associated watersheds (i.e. Local Action Strategies, other jurisdiction/agency specific strategic plans, priority setting documents);*
- *Establish criteria (as needed/appropriate at a national, regional, or jurisdiction scale) of physical, ecological, and sociological factors for identification and prioritization of coral reefs and coral habitats impacted and predicted to be impacted by watershed activities, the type and relative degree of impact, and the potential for reversing decline through management activities;*
- *Identify additional priority coral reefs and associated watersheds through using the above criteria. These priority areas should be map based such that pertinent data and information can be considered in future activities (benthic habitat maps, land types, land-forms, etc.)*

**Objective 1.2:** Identify and prioritize coastal and upland areas for preservation, protection, and restoration based on the coral reef ecosystems and associated watershed areas identified in Objective 1.1.

*Potential activities include:*

- *Coordinate watershed planning activities with other conservation area planning to identify priority forests, tropical meadow, steep slopes, salt pond, mangrove, recharge areas, and other areas that act to buffer pollution to coastal regions.*

**Objective 1.3:** Implement watershed management plans and relevant Local Action Strategies (LAS) within priority coral reef ecosystems and associated watersheds to improve water quality and enhance coral reef ecosystem resilience. Where needed, develop (or update) watershed management plans that incorporate coral reef protection measures.

*Potential activities include:* (refer to Implement existing watershed mgt. plans)

- *NOAA will work with Federal and local partners within targeted priority coral reef watershed ecosystems to develop a watershed implementation plan that:*
  - *Increases staffing, training, and funding within each jurisdiction to implement watershed management plans and management action (see Objective 4.4);*
  - *Proposes further study/research to fill in gaps in understanding;*
  - *Selects diverse Model Watersheds as pilot sites for rapid assessment of management strategies and techniques as a performance tool;*
  - *Develops tools that will help local jurisdictions implement watershed plans;*

- *Leverages support for implementing key projects;*
- *Monitors baseline water quality and reef health;*
- *Monitors projects effectiveness at improving water quality and reef health;*
- *Identifies supplemental actions (increase herbivory, remove algae, etc.) that may be needed to help reverse phase shift.*
- *Work with Federal and local partners to implement priority pollution control actions within priority coral reef watersheds, e.g. upgrade wastewater collection and treatment, install BMPs to reduce stormwater volume and remove pollutants, implement erosion control measures, expand use of effective fertilizer and pesticide management practices, etc.*
- *Improve best management practices in existing urban coastal watersheds in priority coral reef areas*
- *Develop guidance documents for local jurisdictions that identify and describe the best approaches that have been generated through the various watershed management plans and LASSs; guidance should also identify gaps in existing plans and provide an example of a "model" plan.*
- *Share lessons learned across and among jurisdictions.*
- *Support low impact development (LID) training, LEEDS and Green Building training for developers, community planners, and review staff to reduce impact/footprint on remaining natural areas. Identify, support, provide, and assist with funding for identified priority actions and capacity needs.*
- *Identify any/all previously developed watershed plans (governmental entity or a non-governmental organization) and water quality monitoring data which may add information to the reef-watershed prioritization process or pollution mitigation process. These plans should identify the major sources of water quality and pollution threats to the coral reefs and identify key recommended actions to reduce the identified pollution and water quality threats;*
- *Develop new watershed management plans for those priority coral reefs and associated watersheds (identified in Objective 1.1) that do not currently have watershed management plans;*
- *Identify and prioritize the pollutants of concern and their source, for each coral reef watershed (sediment, nutrient, toxic, and microbial (animal specific));*
- *Identify and prioritize the necessary management actions and provide cost estimates broken down by phases where applicable; and*
- *Conduct necessary research to identify stressors at sub-lethal level; identify cause and effect relationship; develop metrics to measure efficacy of management action*

**Objective 1.4:** Promote an integrated effort to fill strategic science gaps that directly inform management decisions related to planning and implementation activities in priority coral reef ecosystems and associated watersheds.

Potential activities include:

- *Establish a dialogue between scientists and managers to promote research questions that will help managers better apply management practices effectively and assess the effectiveness of various types of best management practices*

- *Bridge science, management and policy to develop and translate science into tools useful for managers; integrate biological, physical, and social sciences to meet management needs.*
- *Compile existing baseline and applied research data and determine what additional research is needed for effective management action in priority coral reef watershed areas.*
- *Establish/publish bi-annual applied research agenda to allocate coral program funding specifically for answering priority management questions.*
- *Support the necessary research and/or development of tools needed to assess and address the impacts of pollution on coral reefs at the organismal and community scale. Based on management needs, areas of research should include:*
  - *Identify and document the pollutants and the magnitude of their impact.*
  - *Establishment of quantitative, predictive relationships between water quality (including watershed proxies) and coral reefs (from the organismal to community scale).*
- *Development of GIS Watershed/Marine based “Measures of Disturbance Metrics” or “Index of Biological Integrity” for comparisons of hydrologic alterations and development of coastal watershed impact areas with respect to coral reef health. This index is useful in comparing and prioritizing reef and watershed systems for management by exposing trends, risks and threats to specific watersheds.*
- *Research the effectiveness of various types of best management site design and Green Building practices utilized to address nonpoint source impacts and conduct necessary applied research in Model Watersheds. Examples include: effective bio-engineering for stabilizing steep stream channels, efficient removal of fine silty sediment particles from stormwater run-off, the best seed mix to use for temporary stabilization during construction, mechanisms to stabilize soil in the dry season vs. wet season, and research questions that will help managers better apply management practices effectively.*

**Objective 1.5:** Determine the efficacy of management activities through coordinated baseline and performance monitoring to assess progress and adapt management actions as needed.

Potential activities include:

- *Inventory, by jurisdiction, the monitoring programs for inter-program compatibility. To avoid duplicity, integrate these monitoring efforts to the greatest extent practicable.*
- *Conduct biological and chemical baseline and follow-on monitoring to track changes in each coral reef watershed ecosystem to assess the success of implemented actions and adapt management plans and actions as needed.*
- *Require and track monitoring data for CRCP funded implementation projects. (tracking database)?*
- *Support and coordinate with EPA to satisfy the requirements of the Clean Water Act;*
- *Support jurisdictional efforts to develop and field test coral reef biological criteria. Integrate jurisdiction-wide and priority watershed monitoring with coral biocriteria development by coordinating protocols, assessing gradients in pollutant*

*concentrations, developing pollutant indicators etc. Work with local water quality agencies to integrate coral bioassessments/biocriteria with water quality programs.*

- *Establish metrics that are scientifically defensible, responsive to pollutant stressors, management applicable, and appropriate and relevant to program requirements*
- *Identify stressors at sub-lethal levels*
- *Conduct risk assessments*

**GOAL 2: Promote in-water management activities to restore priority coral reef ecosystems that have been adversely impacted by accumulated sediments, nutrients, and algae.**

Coral reefs persist through the dual processes of reproduction and recruitment, which are dependent on water and substratum quality. Accumulated sediments directly from the adjacent land prevent coral recovery through re-suspension and interference with fertilization, larval development and settlement in corals. Sedimentation and nutrient enrichment can result in shifts from coral dominated to algal dominated systems. In-water management actions such as removal of accumulated sediments and overgrowth of macroalgae can promote coral population replenishment and coral reef health. In some cases these in-water management actions may be needed in lieu of or in addition to reducing pollutant loads from watersheds. In addition to direct in-water management activities, technologies such as remote sensing can provide important data to support management action.

Prior to any direct, in-water management activities, the reef system should be evaluated and a determination made whether reef restoration is warranted or if controlling land-based sources of pollution inputs is sufficient for reef recovery. Examples of possible in-water management action include altering coastal structures to improve flushing and sediment transport, dredging to remove accumulated sediment from the reef system, and physical removal of harmful macroalgae. Developing marine protected areas, stock enhancement programs, or fishery management actions that support the natural maintenance and ecological integrity of the ecosystem may also support recovery of reefs degraded by pollution. Management actions undertaken will be specific to the particular physical and biological characteristics of the selected coral reef ecosystem. Ultimately, this Goal is intended to enhance habitat quality.

This Goal, which supports in-water recovery and restoration efforts to remove and mitigate the impacts of accumulated sediments, contaminants, and nutrients in coral reef ecosystems, is intended to complement the land-based watershed project implementation activities as outlined in Goal 1.

**Objective 2.1:** Identify and prioritize coral reef ecosystems from those prioritized under Objective 1.1 where in-water management activities are needed to promote reef recovery.

Potential activities include:

- *Compile, in collaboration with local governments and stakeholders and consistent with the criteria developed in Objective 1.1, a list of reef areas for consideration in each jurisdiction.*
- *Develop criteria that define reef areas, in each jurisdiction, that are negatively impacted by sedimentation and algal overgrowth;*
- *Assess reef areas, in each jurisdiction to determine which areas meet the impact criteria; for those impacted reef areas, determine sediment sources or causative factors for algal overgrowth;*

**Objective 2.2:** Develop, test, and apply existing or new management tools and technologies that demonstrate the ability to support and promote coral reef protection and recovery, including approaches to remove accumulated pollutants and/or macroalgae to restore healthy environmental & ecosystem conditions.

*Potential activities include:*

- *Develop, implement and sustain remote sensing based indicators, assessments, and observing capabilities/capacity (e.g. satellite, buoy) in support of coral reef management, integrate these efforts with watershed and ocean circulation models, at the appropriate scale;*
- *Protect and enhance populations of herbivorous fishes and invertebrates that can control populations of fleshy algae through marine protected areas;*
- *Examine natural and mechanical means of controlling algal populations to reduce sediment accumulation and retention on reefs*
- *Control nutrient and sediment input into coastal waters, and in collaboration with the Fishing Impacts Working group, develop marine protected areas and stock enhancement programs that support the natural maintenance of ecological integrity;*
- *Develop strategies to eliminate sediment sources, remove excess sediment from the reef system, eliminate the causes of algal overgrowth, and/or eliminate excess sediment and macroalgae from the impacted reef areas.*

**GOAL 3: Build and sustain management capacity at the local level through local, state, regional, and Federal coordination of financial, institutional, and human resources to reduce and prevent the impacts of land-based sources of pollution on coral reef ecosystems.**

Land-based sources of pollution cross multiple jurisdictional boundaries with the authority and responsibility to address them falling to a multitude of governmental and jurisdictional levels. In addition, in many U.S. coral jurisdictions there are varying degrees of community level organization and stakeholder involvement that need to be considered when working to address land-based sources of pollution. It is therefore necessary to build a framework that facilitates enhanced coordination and promotes consistent and strengthened application and enforcement of laws and authorities intended to address land-based sources of pollution.

To be effective, there are several other enabling factors that need to be considered and addressed. Primarily, in many communities it is necessary to first build the local,



regional and federal capacity, including both staff numbers and level of expertise to effectively implement and enforce new or existing mechanisms to reduce land-based sources of pollution. Second, land-based pollution control measures can be expensive to implement and maintain. Therefore, it is essential that new sources of funding and new mechanisms to cost-share are identified and institutionalized. Finally, information needs to be made available for managers, communities, and political leaders, to empower informed decision-making that appropriately considers potential pollutant impacts to coral reef ecosystems.

**Objective 3.1:** Ensure that coral reef jurisdictions have adequate resources and capacity to develop and implement management plans, assess water quality and coral reef ecosystem condition, enforce regulations and evaluate performance.

*Potential Activities Include:*

- *Conduct capacity assessments for each jurisdiction which will:*
  - *Define the skills, knowledge and abilities required of the individuals and public and private institutions to achieve specific strategic coral reef management priorities related to land-based sources of pollution,*
  - *Identify gaps in these skills, knowledge and abilities of the individuals and public and private institutions, and*
  - *Identify a specific suite of actions for increasing human and institutional capacity to address land-based sources of pollution impacts on priority coral reefs, utilizing NOAA, federal and local agency, and NGO resources;*
- *Refer to objective 1.3 for capacity building activities specific to implementing watershed management plans.*
- *Provide funding to support additional staff as needed, based on the capacity needs assessments conducted.*
- *Provide support for jurisdiction to apply for, manage, and report on grants received*

**Objective 3.2** Build partnerships among local, state, federal, and non-governmental entities to identify, leverage, and apply financial and other resources to facilitate improved coastal and upland watershed management to protect coral reef ecosystems from impacts of land-based sources of pollution.

*Potential activities include:*

- *Increase financial resources*
- *Catalog of existing Federal (and state/territory) programs and private organizations that support activities to purchase, preserve, protect, provide easements, and restore coastal habitats (for example: Coastal and Estuarine Land Conservation Program (CELCP), Trust for Public Lands (TPL), U.S. Green Building Council (USGBC), etc).*
- *Identify and partner with existing Federal programs and private organizations that support activities to purchase, preserve, protect, provide easements, and restore coastal habitats.*
- *Develop partnerships that leverage and increase resources available*

- *Increase CELP allocation towards projects (1) located in priority coral watersheds, or (2) identified as high priority parcels in a local/state conservation area plan.*
- *Work with local governments and communities to adopt Comprehensive Land and Water Use Plans, Zoning Plans, and require Green Building and low run-off designs for new development.*
- *Support low impact development (LID) training, LEEDS and Green Building training for developers, community planners, and review staff to reduce impact/footprint on remaining natural areas.*
- *Identify and implement complementary funding opportunities within each priority coral reef watershed.*
- *Coordinate with and support other agency efforts through their specific area of expertise to implement watershed planning efforts (e.g. enforcement, TMDL, agricultural BMPs)*
- *Identify, support, provide, and assist with funding for identified priority actions and capacity needs.*
- *Utilize intergovernmental mechanisms (Objective 4.3) to help leverage and acquire needed funds*

**Objective 3.3:** Support or help develop intergovernmental mechanisms (appropriately designed for each jurisdiction) to promote effective local management actions and decisions.

*Potential activities include:*

- *Identify (by region, jurisdiction, community, and/or watershed) existing intergovernmental relationships and/or organization; assess their effectiveness; develop more targeted partnerships.*
- *Identify needs and opportunities for such intergovernmental relations and/or organizations in jurisdictions that do not currently have them.*
- *Identify key partners in each region/jurisdiction (at the appropriate level and scale needed for that region/jurisdiction).*
- *Develop more targeted and effective partnership opportunities, which identify and utilize specific resources and agency/partner organization expertise to implement projects in priority coral reef areas.(For example, NOAA National Center for Coastal and Ocean Monitoring partnership with the USDA-NRCS Conservation Effects Assessment Program and the Jobos Bay National Estuarine Research Reserve in Puerto Rico, which is an effort to link USDA land conservation practices with NOAA coral ecosystem monitoring activities to determine ecological impacts from land-based sources of pollution.)*
- *Catalog existing intergovernmental mechanisms (i.e. MOUs, Cooperative Agreements, Intergovernmental Personnel Agreements, etc) and develop new mechanisms as needed to facilitate partnership activities as outlined in the above activity.*

**Objective 3.4:** Ensure that the necessary and consistent regulatory and programmatic framework exists and is enforced to implement watershed management strategies necessary to protect coral ecosystems.

Potential activities include:

- *Support development of erosion control contractor /inspector /operator certification programs;*
- *Update stormwater design manuals and local policies/rules to incorporate Low Impact Development;*
- *Support efforts to enhance both regulatory and nonregulatory programs, as well as local enforcement activities, to better address land-based sources of pollution*
- *Support development of a framework for land development/ stormwater management and Green Building and identify gaps or limitations in existing programs and regulations.*

**Objective 3.5:** Increase public and political awareness and understanding of the ecological and socioeconomic impacts of land-based pollution on coral reef resources to promote better stewardship and informed decisions regarding activities in watersheds that may adversely impact coral reef ecosystems.

Potential activities include:

- *Identify and value services (ecological, economic, and social) of coral reefs to local and regional communities and provide information regarding the cost of the loss of such services due to the impact of land based sources of pollution.*
- *Conduct attitude/perception surveys to help guide awareness programs and measure their effectiveness*
- *Develop targeted education and outreach materials at the coral reef watershed ecosystem level.*
- *Support education of elected officials, key constituent groups, and the public regarding matters related to the impacts of land-based sources of pollution on coral reefs, including: beneficial management actions, BMPs for stormwater, individual action, wetland/mangrove/dune protection, etc.*

**References**

- Bellwood, D.R., Hughes, T.P., Folke, C., and Nystrom, M., 2004, Confronting the coral reef crisis: *Nature*, v. 429, p. 827–833.
- Bryant, D., L. Burke, J. McManus, and M. Spalding., 1998, Reefs at risk: A map-based indicator of threats to the world's coral reefs. World Resources Institute, 60 p.
- Fabrizius, K.E., 2005, Effects of terrestrial runoff on the ecology of corals and coral reefs; review and synthesis: *Marine Pollution Bulletin*, v. 50, p. 125–146.
- Fabrizius KE, De'ath G., 2004, Identifying ecological change and its causes: A case study on coral reefs. *Ecological Applications* 14: 1448-1465.
- Field, M.E., Cochran, S.A., Logan, J.B., and Storlazzi, C.D., eds., 2008, The coral reef of south Moloka'i, Hawai'i; Portrait of a sediment-threatened reef: U.S. Geological Survey Scientific Investigations Report 2007-5101, 180 p.
- ISRS, 2004, The effects of terrestrial runoff of sediments, nutrients and other pollutants on coral reefs. Briefing Paper 3, International Society for Reef Studies, pp: 18

- Pandolfi, J.M., Bradbury, R.H., Sala, E., Hughes, T.P., Bjorndal, K.A., Cooke, R.G., McArdle, D., McClenachan, L., Newman, M.J.H., Paredes, G., Warner, R.R., and Jackson, J.B.C., 2003, Global trajectories of the long-term decline of coral reef ecosystems: *Science*, v. 301, p. 955–958.
- Richmond, R.H., Rongo, T., Golbuu, Y., Victor, S., Idechong, N., Davis, G., Kostka, W., Neth, L., Hamnett, M., and Wolanski, E., 2007, Watersheds and coral reefs; conservation science, policy, and implementation: *Bioscience*, v. 57, p. 598–607.
- Richmond, R.H., 1993, Coral reefs: present problems and future concerns resulting from anthropogenic disturbance: *American Zoologist*, v. 33, p. 524–536.
- Rogers, C.S., 1990, Responses of coral reefs and reef organisms to sedimentation: *Marine Ecology Progress Series*, v. 62, p. 185–202.
- Sammarco, P.W., 1996, Comments on coral reef regeneration, bioerosion, biogeography, and chemical ecology: *Future directions*, *J. Exp. Mar. Biol. Ecol.* 200: 135–168.
- Sammarco, P.W., 2008, Crises on coral reefs and in coral reef science in the 21<sup>st</sup> century: The need for a new peer-review system. *Ethics in Science and Environmental Politics* 8: 108–119.
- United Nations Framework Convention on Climate Change (UNFCCC), 2002, Climate Change Information Sheet 13: Water Resources, [http://unfccc.int/essential\\_background/background\\_publications\\_htmlpdf/climate\\_change\\_information\\_kit/items/294.php](http://unfccc.int/essential_background/background_publications_htmlpdf/climate_change_information_kit/items/294.php)
- U.S. Commission on Ocean Policy, 2004, *An Ocean Blueprint for the 21<sup>st</sup> Century*, Final Report, Washington, DC, 676p.
- Wilkinson, C., 2008, *Status of the Coral Reefs of the World: 2008*. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, 296p.